LOGGERHEAD TURTLES IN THE GULF OF MEXICO: PELAGIC DISTRIBUTIONS

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Abstract. Seven seasonal surveys were completed in the Gulf of Mexico to census marine mammals and turtles from the coastline out to the 200 m isobath. Four surveys were completed from the Mississippi River mouth to Brownsville, TX and three were completed from the river mouth to Key West, FL. This sampling method targets loggerhead and leatherback turtles because of their relative size and coloration. The present analyses deal only with the loggerhead turtle which is the most abundant turtle in the Gulf of Mexico. To facilitate sampling, the Gulf of Mexico was divided into two study areas defined as east or west of the Mississippi River delta. Within each study area, sampling strata defined by depth were sampled on a seasonal basis. Depth strata were represented by waters inside barrier islands and land and termed bay waters. Inshore waters extended from the ocean side of islands or the coast out to the 18 m isobath. Offshore waters extended from 18 m to the 200 m isobath. In general, turtles observed and identified to species were sub-adult and adult size loggerhead turtles. In all seasons loggerhead turtle densities were one to two orders of magnitude greater in the eastern Gulf than in the western Gulf. Turtle densities overall were greater in the offshore and inshore waters than in bay waters. There was a concentration of turtles off southwest Florida in the winter, perhaps in response to thermal conditions.

Key Words. Loggerhead sea turtles, aerial surveys, Gulf of Mexico, pelagic distributions

INTRODUCTION

Aerial surveys were first used successfully to census marine turtles regionally in northeast U.S. waters (Winn 1984). Pelagic aerial surveys by NMFS from 1982-1984 demonstrated the utility of using this methodology to census turtles at the surface of the water in the southeast U.S. (Thompson 1987). Results of these programs demonstrated that the application of pelagic aerial surveys is the best method available to sample loggerhead turtles on a regional basis as recently concluded by the National Research Council Committee on Sea Turtle Conservation (Magnuson et al. 1990).

From 1983 to 1986 seasonal surveys were completed over the Gulf of Mexico from the shoreline, including bays and sounds, out to the 200 m isobath to census marine mammals and turtles. Two study areas defined as east and west of the Mississippi River Delta were sampled within three depth strata. Results of these surveys provide the first regional information on the density and distribution of loggerhead turtles within the Gulf of Mexico from Brownsville, Texas to Key West, Florida.

MATERIALS AND METHODS

Survey Methods

The Gulf of Mexico study area was defined primarily using the known distribution of bottlenose dolphins (Tursiops truncatus) which was the primary census species. It was likely that these continental shelf waters represent the primary habitat for loggerhead turtles within southeast U.S. waters. The offshore boundary of the sampling area was delimited by 9.26 km (5 nm) beyond the surface projection of the 200 meter isobath (Figure 1). The total study area was 363,570 km^2. To optimize sampling coverage and facilitate survey completion, the total study area was divided into two sampling areas. The first called the Northwestern Gulf extended from Brownsville, Texas to New Orleans, Louisiana and is 144,056 km^2 in area (Figure 1). The second area, the Northeastern Gulf was from New Orleans to Key West, Florida and is 219,514 km^2 in total area (Figure 1).

Each area was stratified into bay, inshore, and offshore blocks to optimize coverage over varying depths. This delineation is useful for describing the distribution of loggerhead turtles because one hypothesis describes the distribution of large juvenile turtles in bay waters while sub-adult and adult turtles are more likely to be observed in inshore and offshore waters (Lutcavage and Musick 1985; Ehrhart 1983). Sampling coverage of the bays was 15%; for inshore strata coverage averaged 12.5% and was about 7% for the offshore strata. Overall coverage averaged 10% of the water's surface.

The survey platform was a twin engine Beechcraft D-18 equipped with a plexiglass observation bubble on the nose. The observation bubble was calibrated in increments representing right angle sighting distance from the perpendicular or trackline. Sighting intervals were established as: .116, .232, .463, 1.389, 1.852, and greater than 1.852 km from the trackline.

All surveys were flown at 229 m altitude and down to 153 m when circling marine mammals. Survey speed averaged 222 km/hr ground speed. Four observers were included on every flight and two were in the observation bubble at all times during sampling. Observers were rotated at least every hour to minimize fatigue. All possible transects were placed at 2.8 km (1.5 nm) intervals to insure that when sampling adjacent transects, observations would not be duplicated. Transects were randomly selected to represent the average 10% surface coverage based on an effective swath width of 3.7 km.

An Apple II Plus was interfaced with a Loran-C, altimeter and infrared radiometer to automatically input location, altitude and sea surface temperature; time was recorded from the internal computer clock. Data that were input by an off-watch observer included species, number of animals, behavior of the animal, direction of movement of the animal, reliability of species identification, glare amount, Beaufort sea state, observer, and right angle sighting interval.

Data Analysis

The surveys were designed for the application of line transect methods to estimate animal density (Burnham et al. 1980). Distributions of sightings were examined to determine the adequacy of sample sizes within sampling strata for estimating density. Strata and sampling blocks were pooled as necessary to estimate density within each survey; each survey representing a seasonal estimate.

In estimating density, the methods detailed in Burnham et al. (1980) were utilized. In general, density is estimated using:

$$D=n*f(0)/2L$$

where:

D=density
n=number of turtles sighted
f(0)= intercept of probability density function(pdf)
L=total transect length flown

The variance for density was calculated using:

$$Var(D)=D^2[cv(n)^2+cv(f(0))^2]$$

where:

D=density
cv(n)=coefficient of variation of the number of turtle sightings

cv(f(0))=coefficient of variation of the intercept of the pdf

From density, abundance is estimated as:

$$N=A*D$$

where:

A=total sampling block or stratum
D=average density for that block or stratum

The variance for abundance was estimated using:

$$Var(N)=A^2*Var(D)$$

These variance estimators were derived using the delta method described in Seber(1974).

Deriving an intercept from a probability density function requires fitting a curve to the distribution of sightings classified by sighting interval to define a functional form. The FORTRAN program developed by Burnham et al.(1980) to estimate f(0) with five models. These models were the Fourier Series, half-normal distribution, exponential polynomial, exponential power series and negative exponential. The number of sightings used in the estimation of density is the actual number of observations made within each stratum or block for each season. The number of independent sightings recorded can be corrected if glare, sea state and time of day negatively effect the ability to sight a turtle. Corrected values can be used to estimate density and abundance.

The spatial/temporal distributions of sightings were examined to determine the adequacy of sample size within strata for estimating density. Strata and sampling blocks were pooled as necessary to estimate density within each survey; each survey representing a seasonal estimate. Density and abundance were estimated for arbitrarily designated geographical regions as: in the Northwestern Gulf as Texas (TX); and Louisiana (LA); in the Northeastern Gulf as Mississippi, Alabama, Florida to Apalachicola (Panhandle Area); Apalachicola to Sarasota (Central Fl); and Sarasota to Key West, Fl (South Fl). Seasonal density and abundance estimates were completed for each stratum and geographical region.

The sighting rate of turtles along transects was estimated as the number of turtles sighted divided by the total transect length flown. These rates were calculated for each glare code (none, some and severe) and by Beaufort sea state (0,1,2,3). A statistical comparison of sighting rates was completed using a chi-square test for proportions to determine if glare and or sea state had a statistically significant effect on the observers abilities to sight turtles.

RESULTS AND DISCUSSION

Distributions

Gulf of Mexico

Seven seasonal surveys were flown; four in the Northwestern Gulf and three in Northeastern Gulf. The Northwestern Gulf surveys were flown in Sept. to Oct. 1983 (Fall); Jan. to Feb. 1984 (Winter); April to May 1984 (Spring); and July to Aug. 1985 (Summer); Sept. to Oct. 1985 (Fall); and Jan. to Feb. 1986 (Winter). No spring survey was flown. The total transect distance flown for each survey was estimated by stratum and presented in Table 1. The total linear kilometers flown was estimated to be 94,490.5 km in both survey areas, with 44,071.9 km flown in the Northwestern Gulf and 50,418.6 km flown in the Northeastern Gulf.

The total number of loggerhead turtles sighted at the surface of the water was tabulated by survey and for each stratum (Table 2). The total number of turtle recorded was 1192 with 6% of these recorded in the bays; 73% in inshore waters; and 21% in the offshore waters. During the previous NMFS surveys it was determined empirically that the average minimum size of turtles that are sighted at a survey altitude of 153 m is about 61 cm (2ft.) straight line carapace length. Thus, if there is a linear relationship between size of turtle sighted and survey altitude and there is no reason to make this assumption, the turtles sighted were at least 92 cm (3 ft.) in straight line carapace length. This (92 cm) is certainly well within the average length of nesting females throughout the southeast U.S. (Dodd 1988). While there is no reason to assume a linear relationship between turtle size observed and survey altitude, it is likely that at 229 m altitude the majority of turtles sighted are in the sub-adult and adult size classes.

Northwestern Gulf of Mexico

The surveys in the Northwestern Gulf of Mexico netted a total of 57 reported sightings of loggerhead turtles, with sightings per surveys presented in Table 2. Given the linear estimated transect length by survey (Table 1), sightings per unit of survey effort as measured per kilometer was calculated (Table 3). No sightings were recorded in the bay waters of the Northwestern Gulf sampling area. This does not mean that there were no turtles in these waters, but that no adult, sub-adult or large juvenile turtles were visible at the surface under survey conditions. Water color or turbidity could not be ruled out as a factor because it is highly variable within bay waters. However, it is more likely that turtles were too small for detection (Ogren personal observation).

The overall sightings of turtle per kilometer of trackline flown was estimated as .0013 (Table 3). Within the inshore and offshore waters, the sighting rate ranged form 0 to .0048 turtles per km (Table 3). A chi-square computation to test the independence of sighting rate from stratum and survey resulted in acceptance of the null hypothesis; that sighting rate was independent of survey or stratum (Fleiss 1973; X^2=.23, p.950). While there appears to be a greater likelihood of sighting turtles in the inshore and offshore waters during the fall, this is not supported statistically because so few turtles were recorded during any one survey(Fig.2)

Northeastern Gulf of Mexico

A total of three surveys were flown in the Northeastern Gulf with a total of 1,135 loggerhead turtles recorded during these surveys (Fig. 3). The number of turtle recorded by survey and stratum are present in Table 2. As before, sightings per unit of linear transect flown was estimated and included in Table 3. Estimated sighting rate is a better indicator of differences in turtle sightings rather than the absolute frequency of sightings relative to season or stratum because this index corrects for unequal sampling effort. A statistical comparison of rates demonstrated that there were significant difference in sighting rates between seasons and strata (X^2=11.88, p<.005;Fleiss 1973).

The mean rate over all seasons was estimated as .0093 loggerhead turtles per kilometer (Table 3). The sighting rate in all inshore surveys was greater than all offshore surveys which was greater than all bay surveys (Table 3). The smallest value was estimated for the winter bay surveys (.0008) and the largest value for the fall inshore survey (.0180) (Table 3). For the bays and inshore waters the greatest sighting rates were estimated for the fall surveys, whereas the winter surveys resulted in the greatest sighting rate in the offshore strata (Table 3).

The stratified sighting rates in this area are all at least one magnitude higher than in the Northwestern Gulf. However, the trend is the same suggesting the turtle behavior, environmental conditions and or observer behavior was consistent throughout the Gulf during the sampling period.

Numerical Estimates

Effects of glare and sea state on sighting rates

Sightings of turtles were used to calculate sighting rates classified by glare amount and Beaufort sea state. Glare was divided into two subjective categories for the purpose of this analysis: present or absent. Glare level was noted by each observer for the right and left sides and was generally noted when glare level changed. Sea state was reported using the standard Beaufort scale where: 0=glassy, 1=ripples, 2=wavelets, and 3=scattered whitecaps. When sea state over more than half the flight line were reported to be sea state greater than 3, the flight was not included. Therefore, the classification of sighting rates by sea state is limited to sea states 0 to 3.

The effect of glare and sea state on the ability to sight turtles at the surface of the water was determined by comparing sighting rates classified by each glare code and sea state code. Thus, each cell value represents the total sightings divided by the transect length flown for each glare and sea state code. The comparisons were completed using the chi-square contingency test for proportions (Fleiss 1973). The preponderance of zero values for moderate and severe glare levels is not unexpected (Table 4). The apparent effect of sea state is somewhat unexpected when all surveys are pooled. Under conditions of no glare, sea state one or two resulted in a greater sighting rate than sea state zero (Table 4). This effect is most noticeable in the inshore waters, where the majority of sightings occurred. This effect is not apparent in inshore waters under slight glare conditions (Table 4). Sea state and glare significantly impact sighting rate for the bay and inshore waters (X^2=102.64, p<.001; X^2=13.45, p<.005 respectively). Sighting rates in bay waters were remarkably consistent suggesting that either observer behavior, turtle behavior and/or environmental conditions were spatially consistent.

Sighting rates were also calculated for each glare, sea state code, stratum and survey to determine if there were seasonal glare or sea state effects on sightings. Obviously, the additional breakout by survey or season results in more zero cell values which will dilute the previous results. However, even with the addition of the seasonal variable there were significant effects in inshore waters during the summer and fall surveys, and in the offshore waters during the winter (Table 5). Whether this reflects a consistency of observer or turtle behavior or environmental conditions cannot be determined, but the effect remains significant and apparently dependent upon depth stratum.

Density and abundance estimates

Estimates of loggerhead turtle density, defined as the numbers of turtles at the surface per km^2, were developed for each survey and stratum in the Northwestern and Northeastern Gulf areas respectively. The number of turtles sighted was sufficient to allow for density estimation in the Northeastern Gulf but not in the Northwestern Gulf.

Sightings were classified by sighting interval and the resulting frequency distributions are presented in Figures 3 and 4 for the Northwestern and Northeastern ares respectively. The number of turtles reported within the first sighting interval was less than the number of turtles observed in the second sighting interval for each survey and stratum. Fitting forms to these distributions would result in negatively biased estimates and also violates a criterion of Burnham et al (1980) for robust estimation, that the functional form of the sighting distribution should have a shoulder. When the form is scaled to a probability density function, the probability of sighting an animal on the trackline or is one. Detection errors in the first interval may have resulted from turtles either not being present in this interval or being missed by the observers. The effective half swath width from the SeTS program, the maximum distance turtles were observed from the trackline, was between .16 and .25 km (Thompson 1984). The optimal observation of marine mammals requires the observer to scan from the trackline out to the horizon, while previous results have indicated that .25 km from the trackline is the maximum perpendicular sighting distance for turtles in this platform. This necessity for marine mammal observation may compromise the effective viewing area for turtles and would result in reduced sightings about the trackline.

Functions fit to the observed distributions will be negatively biased as a result of this heaping in the second sighting interval. The options for reducing this bias are to pool the first two intervals; utilize the beginning of the second interval as the trackline; and ignore the first interval and fit the form to the resulting distribution through to the trackline. The third option may result in a positively biased estimate of f(0) since the true form is unknown. The second option may result in either negatively or positively biased estimates because the true from is not known. The first option will likely provide negatively biased results and was the option selected for model fitting because it was considered best to underestimate turtle density rather than overestimated density.

The five models were fit to sighting distributions stratified by stratum, glare amount and Beaufort sea state. Using the criteria outlined by Burnham et al (1980) as applied to the estimation of f(0) resulted in the selection of the half-normal in all cases (Table 6). The effective half swath width was estimated as the reciprocal of the value of f(0) and is included in Table 6. A comparison of the estimated f(0) for bays, inshore and offshore waters respectively resulted in no difference from the estimate of f(0) for all strata pooled. The estimates have coefficient of variation of about 10% or less, with the least precision in the bays where sample size was the smallest, and the greatest precision in the inshore waters where the sample size was the largest. Neither glare nor Beaufort sea state have a significant effect on the estimation of f(0). The effect of glare and sea state on sighting turtles appears to have been consistent between observers. Estimation of density was completed using the estimates of f(0) derived for the entire survey areas, and by depth strata when appropriate. Density was estimated for: 1) the entire Gulf of Mexico; 2) the Northeast and Northwestern Gulf 3) stratified by bay, inshore offshore and season and 4) geographic regions within the Northwestern (TX and LA) and Northeastern Gulf (Panhandle, Central Fl and South Fl).

Density and abundance in the Northeastern Gulf were estimated using values of total sightings corrected for the negative effect of glare and sea state on the observers abilities to sight turtles bases on the results presented in Table 4.

The average density within the Gulf of Mexico was estimated as .0026381 (±2SE as approximate 95% confidence intervals) turtles per km^2. Seasonal turtle density within the Northwestern Gulf was estimated to be one two orders of magnitude lower than that for the Northeastern Gulf (Table 7). Within the Northwestern Gulf study area, there was no difference in the estimated density of turtles in the spring, fall or winter (Table 7). However, the density of turtles in the summer was significantly lower than in the spring, fall or winter (Table 7). In the Northeastern Gulf, the density of turtles was greatest in the fall survey and smaller in the winter but there were no statistically significant differences between seasons (Table 7). The precision of the estimated densities is high for the Northeastern Gulf and low for the Northwestern Gulf (Table 7).

The number of sightings classified by stratum and geographical area as previously described were sufficient for density estimation in the Northeastern Gulf study area only (Table 7). Within the bays of the Northeastern Gulf, the greatest density was estimated for the fall survey and the smallest for the winter (Table 7). In inshore waters both the summer and fall turtle densities were greater than in the winter (Table 7). In offshore waters, the fall and winter surveys demonstrated higher densities than the summer. In all areas, densities were consistently highest in the fall (Table 7). Comparing densities by stratum within each season indicates that densities were highest in the inshore waters in the summer and fall and highest in the offshore waters in the winter (Table 7). Turtle density was estimated for each stratum and survey within each geographical region (Tables 8 and 9). In the Northwestern Gulf, turtle densities were highest in the fall and lowest in the winter in Texas and the highest in the winter. In Louisiana no turtles were reported during the spring survey and the highest density was estimated for the winter (Table 8). Overall, there were not large numbers of loggerhead turtles observed in the Northwestern Gulf, therefore, seasonal trends cannot be identified. It is not known whether loggerhead turtles in the Northwestern Gulf are seasonal migrants and this cannot be elucidated from the present results.

In the Northeastern Gulf, sufficient turtles were observed to suggest seasonal movements. Overall bays demonstrated relatively low densities. The highest bay value was derived for the fall survey in central Florida waters and the lowest during the fall and winter surveys of the Panhandle waters (Table 9). Within the inshore waters the highest turtle density was estimated for southwest Florida waters during all seasons and the lowest for the northernmost region (Table 9). Consequently, in offshore waters the southernmost region showed the greatest turtle density and was significantly higher than in the northernmost region (Table 9).

Numerical abundance estimates accompany all density values and are included in all tables. Examining all estimates of abundance classified by season, stratum and geographical region, results in a high of 7,229 loggerhead turtles within the southwestern Florida offshore waters in the winter and from 5-11 turtles estimated for all bay waters in the summer, southwestern Florida bay waters and northern inshore waters in the winter. The only survey that yielded more than tens of turtles in the bays was off central Florida in the fall (Table 9). The possibility that this may have been a function of water clarity was ruled out because water clarity was highly variable within all strata and between seasons. If Kemp's ridleys utilize these waters, the size and coloration of this species is such that it would likely not be sighted via aerial surveys conducted at 229 m altitude. The behavior of animals in these bay waters may also prohibit sightings if the animals spend much time on the bottom as compared to time at the surface. While these results could be interpreted to mean there are few turtles in bay waters, other studies have shown that this is not the case and the lack of sightings is either the result of environmental conditions, turtle size or behavior or some combination of these factors rather than an absence of turtles.

Based on these results it appears that during the study period, turtles were most visible in the offshore waters of southwestern Florida in the winter. Turtles were also numerous in southwestern Florida inshore and offshore waters in the summer; in southwestern Florida inshore and offshore waters and central Florida inshore waters and the fall; and southwestern inshore waters in the winter. Thus, distributions of turtles appear to be more uniform in the inshore and offshore waters in the summer and move toward southwestern offshore water sin the winter. Turtles appeared to be less likely sighted at the surface in the northern most region and abundance was consistently one order of magnitude lower than for the other two regions (Table 9).

CONCLUSIONS

Results from these aerial surveys serve as a baseline for the distribution and abundance of loggerhead turtles in the Gulf of Mexico. The loggerhead turtle is clearly a successful target for pelagic aerial surveys on a regional basis. Results of these surveys show that the distribution of this species throughout the Gulf is skewed toward the eastern Gulf, from the Mississippi River

Delta to Key West Florida. The relative lack of sightings in the western Gulf is not to be interpreted to mean that there are no marine turtles in this area. Historically, the green turtle was known as the Texas turtle and was the focus of an active fishery in the Corpus Christi area at the turn of the century (Hildebrand 1982). The Kemp's ridley turtle was known historically as the Louisiana turtle (Hildebrand 1982). Thus, both species have been reported as present and even common in specific areas of the Gulf of Mexico but were not detected by our pelagic aerial surveys. The green turtles carapace coloration does not provide the same dramatic contrast as that of the loggerhead and is probably easily over looked. The Kemp's ridley coloration also does not provide a visual contrast against the water and as the smallest species is probably not large enough for detection at 229 m altitude and at 22 km/hr speed.

This east-west dichotomy in the distribution of loggerhead turtles is supported by the results of previous aerial surveys in the Gulf conducted by the US Fish and Wildlife Service (FWS) in 1980-1981 (Fritts et al. 1983). In these surveys loggerhead turtles were sighted 50 times more frequently off the southwest coast of Florida compared to off the Louisiana and Texas coasts (Fritts et al. 1983). Results of these bimonthly surveys indicated that this distribution showed seasonal shifts as well, within the highest frequency of sightings occurring in the spring the lowest in the winter (Fritts et al. 1983). Our survey results suggest that there may be seasonal movements also from the central Florida inshore and offshore waters in the fall to the southwest Florida inshore and primarily offshore waters in the winter. Fritts et al (1983) estimated turtle density off the southeast coast of Florida and the highest was estimated for February 1981 (.22 turtles per km^2) and lowest in October 1980 (.061 turtles per km_2). Our results also demonstrated an aggregation of turtles in southwest Florida waters during the winter.

The FWS survey extended from the coastline out to the approximate 1000 m bathymetric curve but very few sightings were made beyond the 100 m curve (Fritts et al. 1983). Both inshore and offshore waters of central and southwest Florida in the present surveys supported numerous turtles out to the western boundary of the offshore sampling areas (Fig. 3). Thus, it appears from these recent surveys that loggerhead turtles are abundant and conspicuous in the eastern Gulf off the coast of Florida and significantly less abundant or conspicuous in the northern and western Gulf waters where they probably move from north central Florida to the southwest offshore waters in response to reduced temperatures in the winter or as they follow an available resource.

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Table 1. Total transect kilometers flown for each season in the Northwestern and Northeastern Gulf of Mexico. Linear distance is reported for each depth stratum within each season.

Survey	Stratum			
	Bays	Inshore	Offshore	Total
Northwestern Gulf				
Fall	2,011.1	2,701.4	5,101.5	9,814.0
Winter	1,810.6	3,198.6	5,543.8	10,553.0
Spring	2,688.9	3,269.5	4,847.1	10,805.5
Summer	3,293.0	3,863.1	5,743.3	12,889.4
Northeastern Gulf				
Fall	3,354.9	6,479.8	6,150.9	15,985.6
Winter	5,371.6	6,800.4	3,338.7	15,510.7
Summer	5,932.8	8,396.7	4,592.8	18,922.3
Total	24,462.9	34,709.5	35,318.1	94,490.5

Table 2. Numbers of loggerhead turtles sighted in the Northwestern and Northeastern Gulf of Mexico during seasonal surveys from 1984-1987. Sightings are reported by season and for each depth stratum.

Survey	Stratum			
	Bays	Inshore	Offshore	Total
Northwestern Gulf				
Fall	0	13	2	15
Winter	0	0	14	14
Spring	0	8	14	22
Summer	0	3	3	6
Northeastern Gulf				
Fall	36	284	87	407
Winter	9	193	82	284
Summer	26	371	47	444
Total	71	872	249	1,192

Table 3. Mean number of turtles sighted per linear kilometer of selected transects flown. These sighting rates are presented for the Northwestern and Northeastern Gulf study areas by depth stratum and season. The mean sighting rate over all states for each season is included.

Survey	Stratum			
	Bays	Inshore	Offshore	Total
Northwestern Gulf				
Fall	0	.0048	.0004	.0015
Winter	0	0	.0025	.0013
Spring	0	.0025	.0029	.0020
Summer	0	.0008	.0005	.0005
Northeastern Gulf				
Fall	.0051	.0180	.0070	.0111
Winter	.0008	.0131	.0109	.0083
Summer	.0019	.0158	.0051	.0085

Table 4. Mean number of turtles sighted per kilometer of trackline in the Northeastern Gulf under Beaufort sea state (BSS) conditions as reported of 0, 1, 2 and 3; and with surface glare (1) or without glare (0). Sighting rates are presented for each depth stratum pooled over all seasons.

	Bays			Inshore			Offshore	
	Glare			Glare			Glare	
BSS	0	1	BSS	0	1	BSS	0	1
0	.0000	.0000	0	.0480	.0654	0	.0000	.0000
1	.0056	.0018	1	.0712	.0298	1	.0215	.0064
2	.0045	.0043	2	.0298	.0205	2	.0239	.0109
3	.0040	.0014	3	.0235	.0086	3	.0104	.0023
	Chi-square = 102.64			Chi-square = 13.45			Chi-square = 5.38	
	$\alpha < .001$			$\alpha < .005$			$\alpha < .10$	

Table 5. Chi-square values and levels of significance resulting from comparing sightings of turtles per kilometer in the Northeastern Gulf classifed by season, depth stratum (B, I, O for bays, inshore and offshore), Beaufort sea state (0-3) and the presence or absence of glare (1, 0).

	Fall				Winter				Summer		
	B	I	O		B	I	O		B	I	O
Chi-square	.210	2.423	.414	Chi-square	.004	.394	7.114	Chi-square	.006	8.19	.173
α	< .75	<.10	<.50	α	<.90	<.50	<.01	α	<.90	<.005	<.750

Table 6. Estimated values of f(0) for each sampling station, bays; inshore; offshore. Five models were fit to distributions of turtles classified by sighting interval with frequency of sighting pooled over intervals 1 and 2. The coefficient of variation of each estimated f(0) is included as a percent, with α level of significance of computed chi-square.

Model	Bays			Inshore			Offshore		
	f(0)	cv	α	f(0)	cv	α	f(0)	cv	α
Fourier Series	No Convergence			3.376	3.5	.000	3.641	5.5	.000
Negative Exponential	6.525	14.7	.009	5.586	5.8	.000	6.528	7.7	.000
Exponential Polynomial	4.105	10.5	.009	3.939	2.9	.000	4.220	5.4	.000
Exponential Power Series	3.134	4.6	.009	3.341	5.9	.000	3.342	7.1	.000
Half Normal	4.077	10.1	.144	3.533	4.8	.309	4.055	5.3	.029

Table 7. Estimated turtle density (D) and abundance (N) for the Northwestern (NW) and Northeastern (NE) Gulf study areas. Estimated density and abundance are presented for each season and for each depth stratum where B=bays, I=inshore, and O=offshore waters. SE=strandard error of the estimated density and abundance.

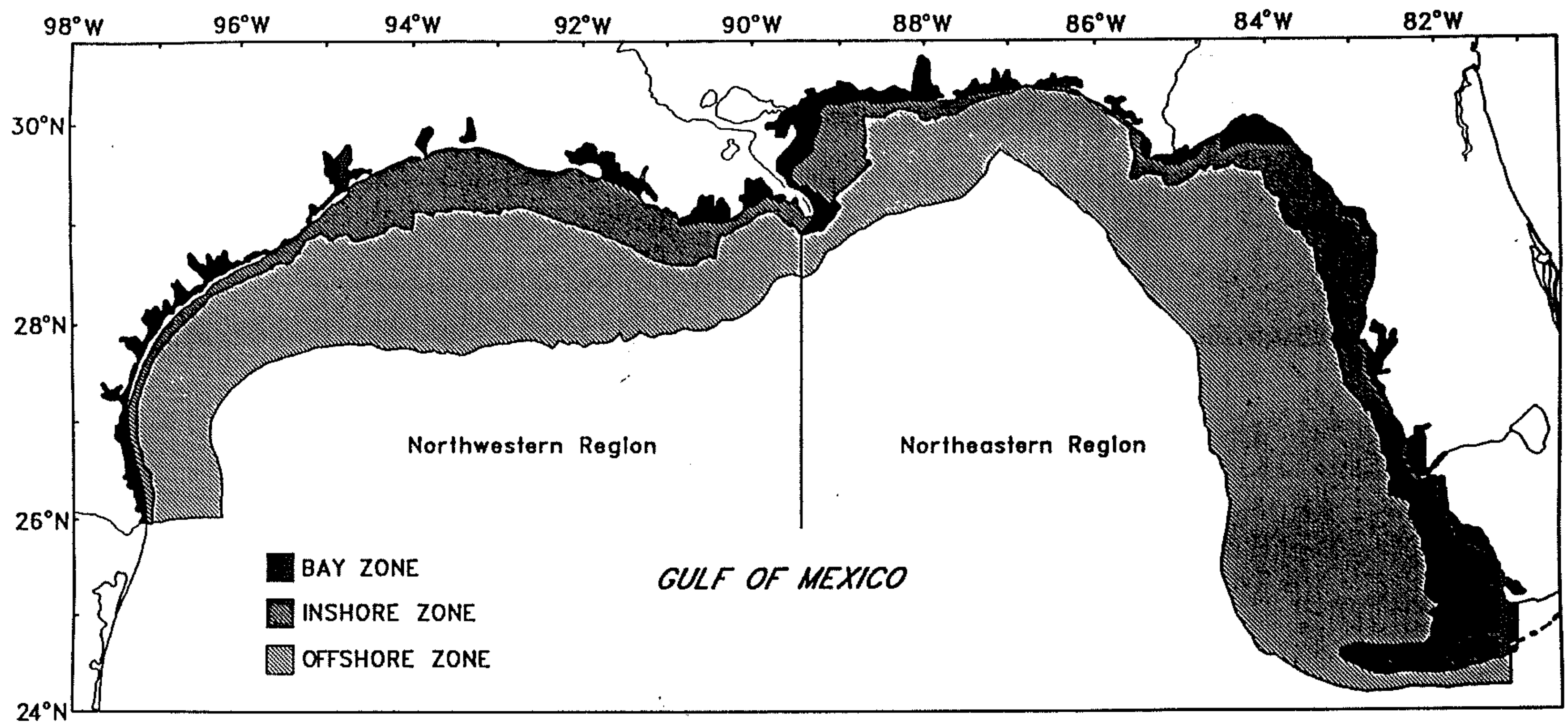
	B				I				O			
	D	SE	N	SE	D	SE	N	SE	D	SE	N	SE
NW												
Fall	0	0	0	0	.00206	.00016	122.7	9.8	.00060	.00010	90.5	15.8
Winter	0	0	0	0	0	0	0	0	.00232	.00016	526.2	35.4
Spring	0	0	0	0	.00094	.00009	212.5	21.4	.00341	.00023	774.5	52.1
Summer	0	0	0	0	.00032	.00005	73.02	12.0	.00060	.00009	136.9	19.6
NE												
Summer	.00671	.00134	953.9	194.3	.03742	.00241	5318.1	344.5	.00908	.00136	1289.9	194.7
Fall	.01316	.00225	1870.2	320.0	.03919	.00278	5569.6	394.7	.01557	.00176	2122.4	252.2
Winter	.00302	.00101	32.33	10.9	.02530	.00207	905.8	74.1	.02084	.00243	2961.3	346.6

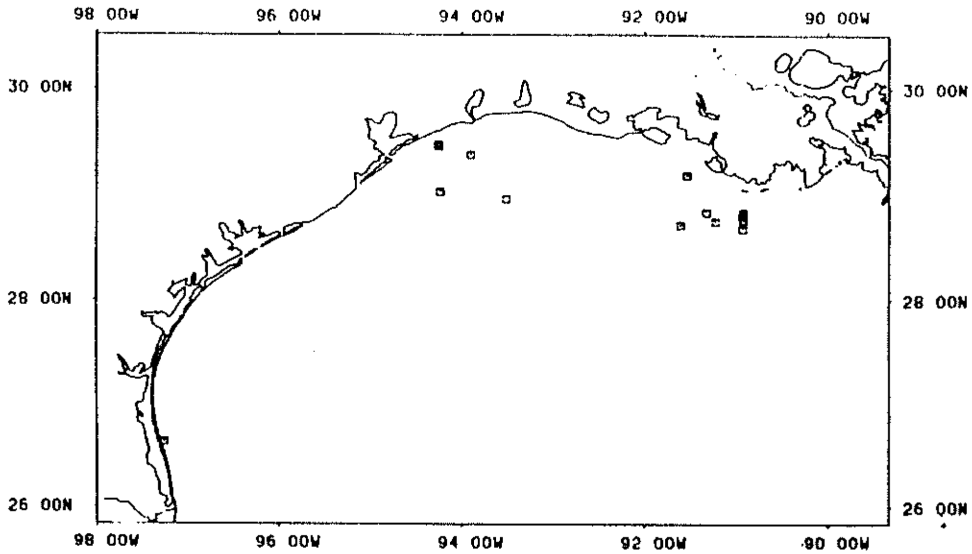
Table 8. Estimated turtle density (D) and abundance (N) for the two Northwestern Gulf regions, LA=Louisiana west of Mississipi River Delta and TX=Texas. Estimated density and abundance are presented by season over all depth strata for LA and TX. SE=standard error estimated for density and abundance.

	LA				TX			
Season	D	SE	N	SE	D	SE	N	SE
Fall	.00065	.00017	46.2	12.5	.00429	.00033	312.8	23.8
Winter	.00329	.00040	234.6	28.6	.00031	.00008	22.9	6.2
Spring	0	0	0	0	.00229	.00022	166.8	16.1
Summer	.00185	.00028	132.0	23.8	.00071	.00011	51.5	8.1

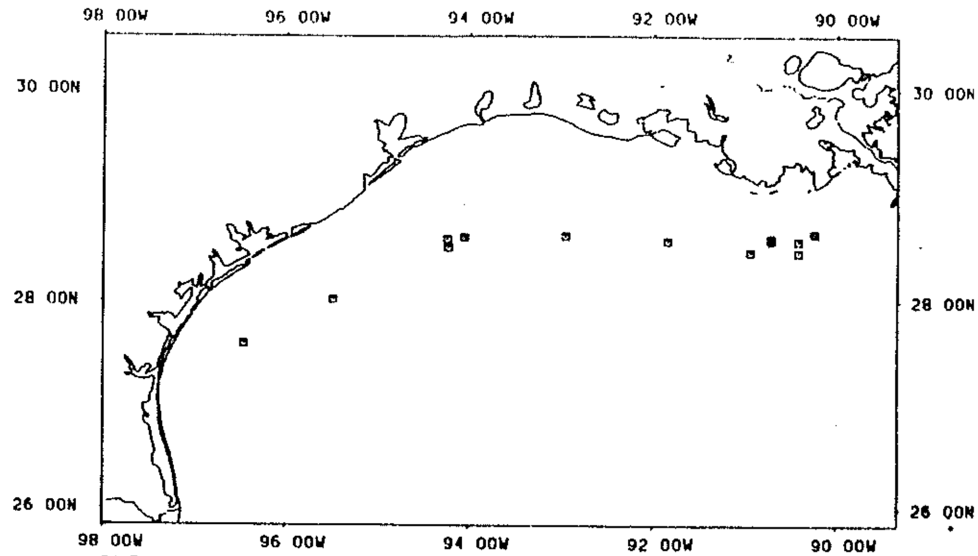
Table 9. Estimated turtle density (D) and abundance (N) in the Northeastern Gulf study area. Estimates are presented by season, depth stratum (B=bays; I=inshore; O=offshore) and geographical region (P=panhandle; C=central; S=south). Included are estimated standard errors (SE) for density and abundance. NS=not sampled.

Season	Stratum	Area	Density	SE	N	SE
Summer	B	P	.0009	.0009	4.56	4.48
		C	.0035	.0100	4.05	5.60
		S	.0092	.0060	11.09	4.27
	I	P	.0161	.0145	71.54	64.26
		C	.0438	.0204	824.62	376.66
		S	.0765	.0046	1,495.63	90.03
	O	P	.0184	.0040	665.78	141.86
		C	.0242	.0052	1,551.69	661.04
		S	.0188	.0109	960.95	319.74
Fall	B	P	0	0	0	0
		C	.0342	.0033	110.61	3.03
		S	.0299	.0072	27.83	1.85
	I	P	.0543	.0124	240.52	12.99
		C	.0502	.0064	945.42	231.24
		S	.1309	.0103	2,559.41	246.27
	O	P	.0101	.0030	364.93	31.52
		C	.0508	.0072	3,257.61	64.16
		S	.0261	.0060	1,329.90	306.81
Winter	B	P	0	0	0	0
		C	.0048	.0634	15.88	11.45
		S	.0063	.0026	5.91	1.00
	I	P	.0012	.0006	5.50	1.34
		C	.0172	.0043	323.35	609.00
		S	.0883	.0072	1,727.15	139.79
	O	P	.0113	.0037	407.22	131.09
		C	NS	NS	NS	NS
		S	.1416	.0161	7,229.22	92.70

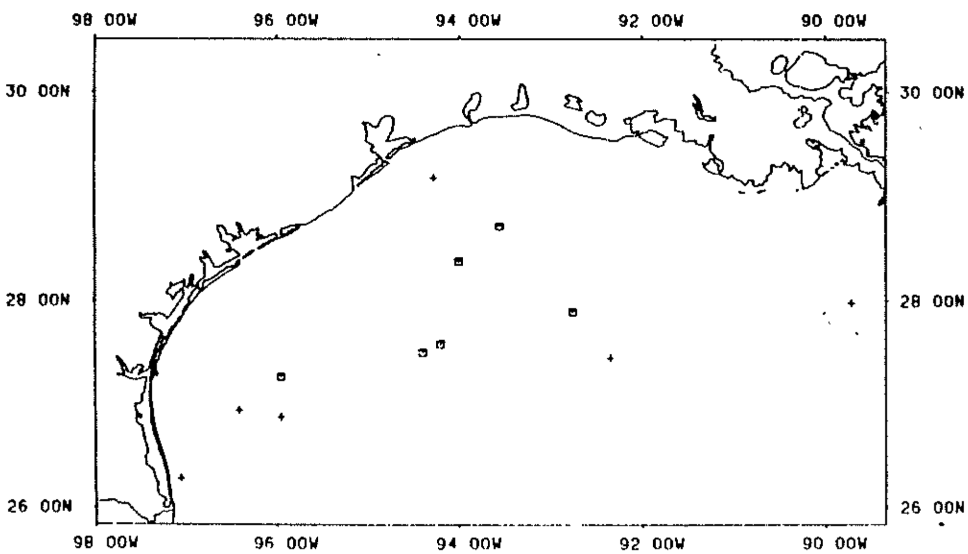

98°W
96°W
94°W
92°W
90°W
88°W
86°W
84°W
82°W
30°N
28°N
26°N
24°N
Northwestern Region
Northeastern Region
GULF OF MEXICO
BAY ZONE
INSHORE ZONE
OFFSHORE ZONE



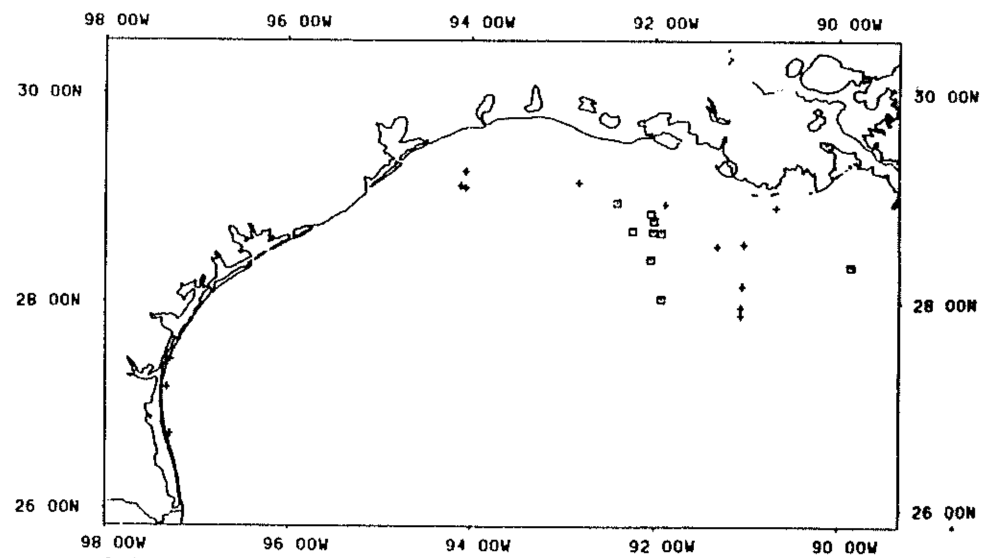
SURVEY 1, LOGGERHEAD TURTLE SIGHTINGS (N=14)



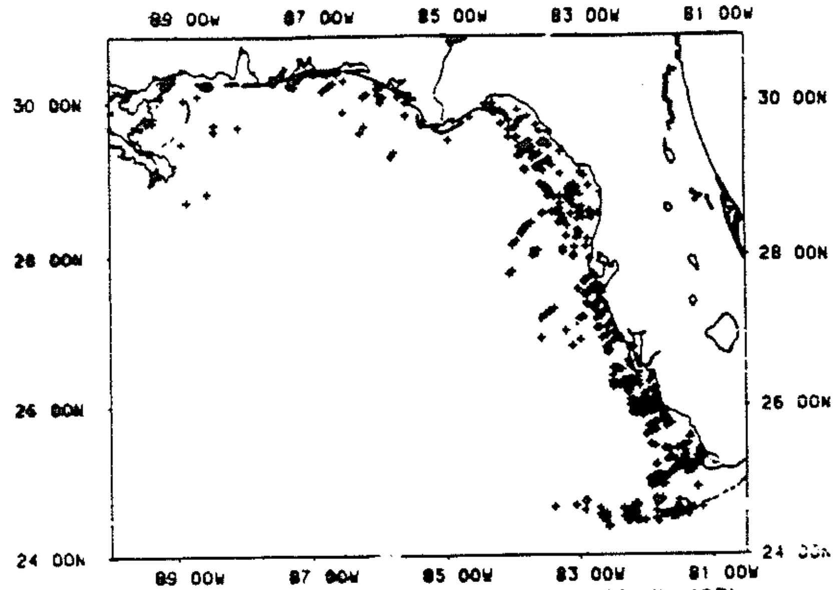
SURVEY 2, LOGGERHEAD TURTLE SIGHTINGS (N=13)



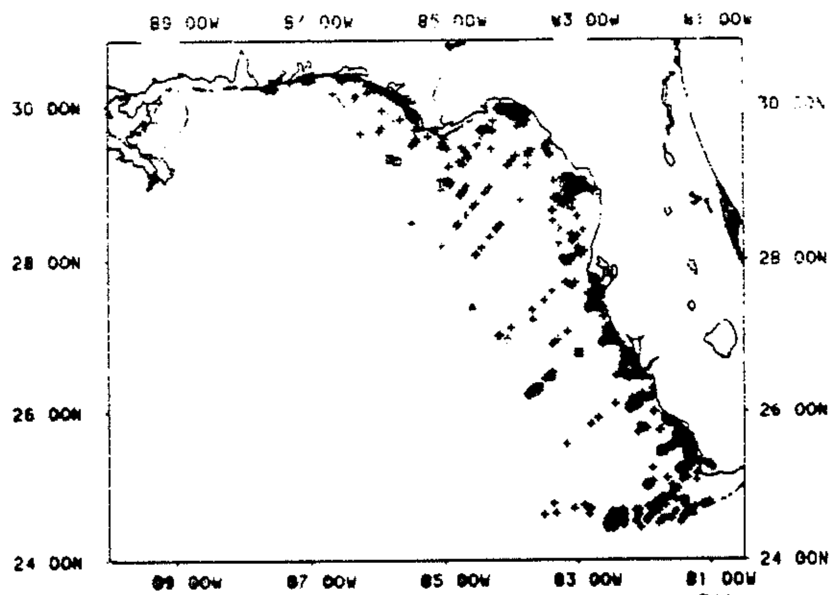
SURVEY 4, LOGGERHEAD TURTLE SIGHTINGS (N=13)



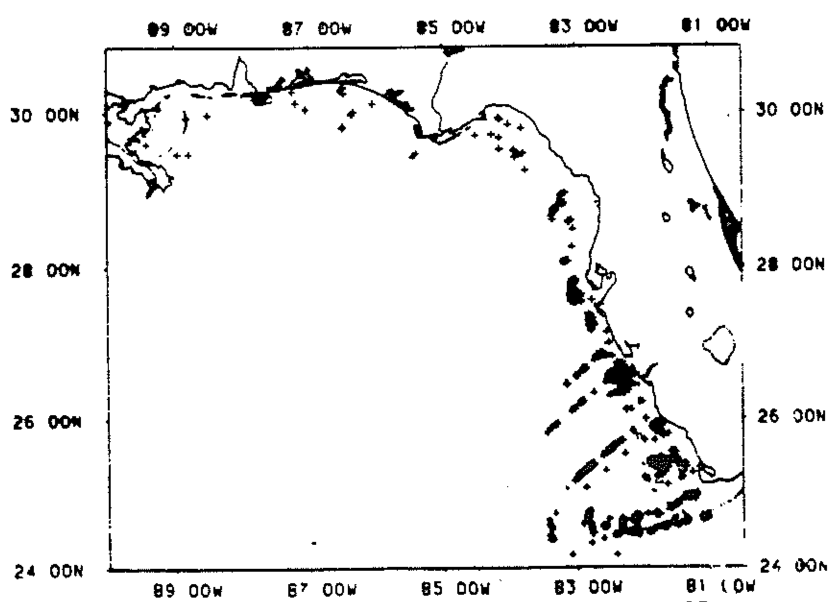
SURVEY 3, LOGGERHEAD TURTLE SIGHTINGS (N=23)



SURVEY 5. LOGGERHEAD TURTLE SIGHTINGS (N=463)



SURVEY 6. LOGGERHEAD TURTLE SIGHTINGS (N=431)



SURVEY 7. LOGGERHEAD TURTLE SIGHTINGS (N=339)